# Transparent Yb:YAG ceramic laser gain media


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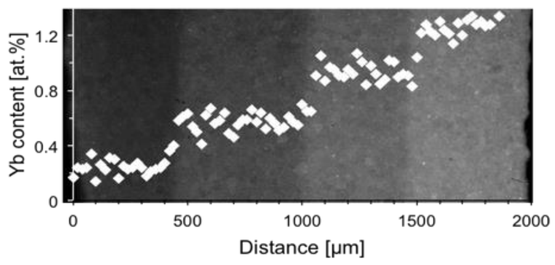
Yb-doped YAG ceramic materials are often proposed to substitute single crystals as the **active source in solid state lasers**, mostly due to the advantages of the ceramic processing with respect to the single crystal growth process. **Ceramics** are prepared with a **fast, cost-effective and flexible process**, can be shaped with complex geometries and with a controlled dopant distribution and exhibit outstanding laser efficiency. Thus, **ceramics represent the ideal candidate for high power laser materials**. The presented work deals with the production of ytterbium-doped yttrium aluminum garnet (Yb:YAG) transparent ceramics. The materials were prepared from commerical oxide powders and processed to transparent quality by vacuum sintering.


## Structured ceramics

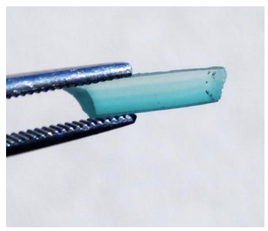
To mitigate thermal and thermo-mechanical effects that deteriorate the laser efficiency at high thermal loading (high power), structured doping is proposed: materials with layered and gradient dopant concentration distribution. [1]



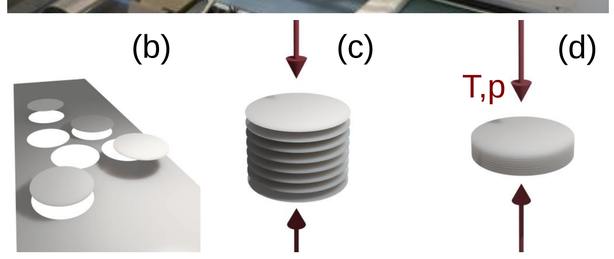

## Tape casting

The tape casting method is based on the casting of a suspension with plasticizrs and binders on a plastic sheet in order to obtain a thin layer (tape) which remains flexible after drying. The tapes can be assembled, stacked and united into a single bulk piece by compression at elevated temperatures (60 – 100 °C).

Layered structure is obtained by stacking of tapes with different dopant content. [4]

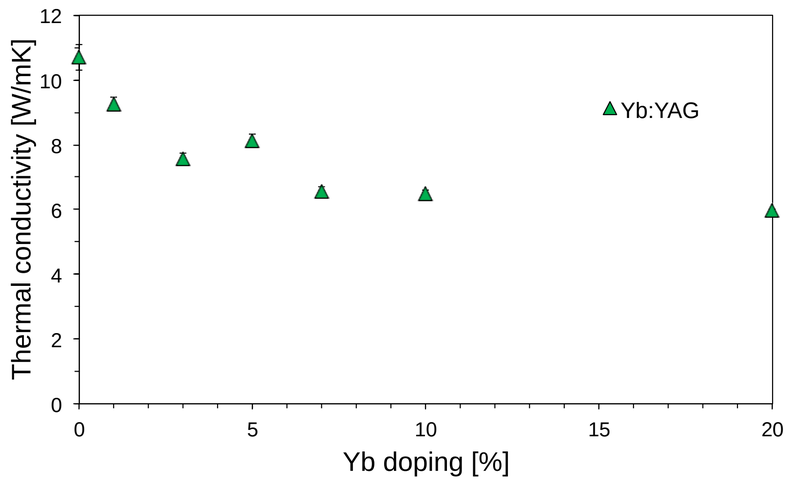



Sample prepared by tape casting.




Tape casting process: suepnsion is cast on a mylar sheet and dries into tape; desired shapes are cut from the tape, stacked upon one another and compressed at elevated temperature.

## Thermal conductivity

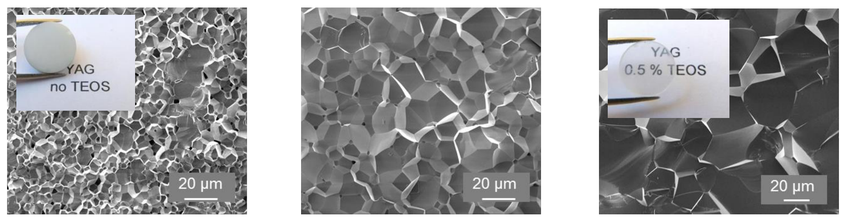



Thermal conductivity of Yb:YAG ceramics decreases with the addition of Yb in the range of 0 – 20%, with a significant decrease with the introduction of the first few percent of the dopant. The measurement was performed by the laser flash and xenon flash techniques.[2] Thermal properties play an important role in the design of laser devices.

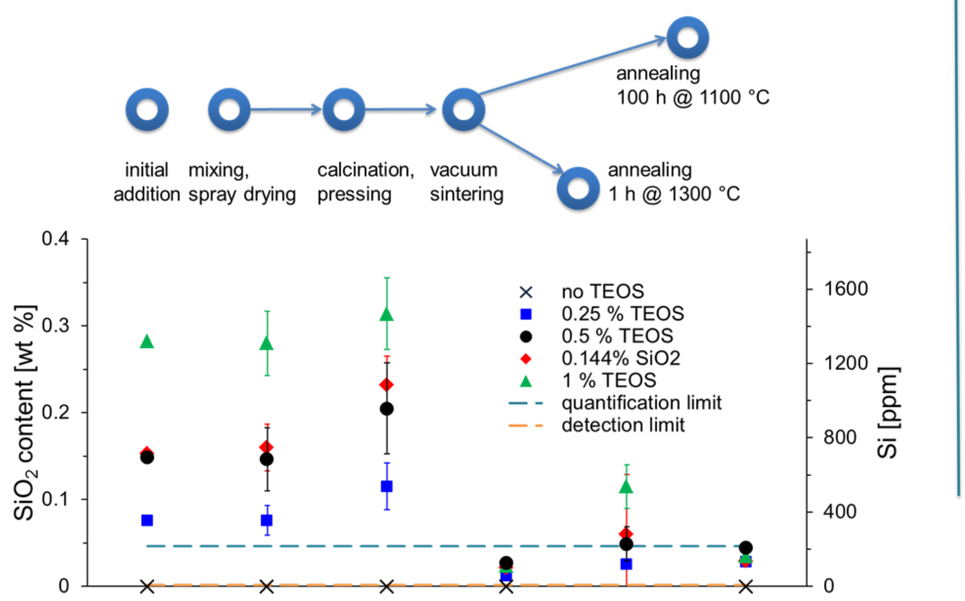
## Sintering additives

The use of additives, sintering aids, is of major help in the achievement of transparency in ceramics. In the case of YAG we used a precursor of $SiO_2$, teraethyl orthosilicate (TEOS). The effect of TEOS on the microstructure and transparency is shown below:

0% TEOS | 0.25% | 0.5%




The amount of silica was monitored by laser-induced breakdown spectroscopy (LIBS). A significant decrease (> 80 %) was observed after vacuum sintering. [3]




## Conclusions

- The obtained materials are **Yb-doped YAG ceramics** with a homogeneous microstructure and good optical quality, and have been successfully tested as laser gain media.
- The concentration of silica (sintering additive, introduced by TEOS) was measured by LIBS. A major evaporation of silica occurs during vacuum sintering.
- Thermal conductivity of YAG with different Yb content was measured. **The addition of dopant leads to a decrease of conductivity** and thus complicates the cooling of the laser.
- Some of the thermal issues may be prevented by the design of the dopant distribution within he laser gain medium.
- **Complex structures** can be prepared via the ceramic process, in particular using the advantageous **tape casting** process followed by thermal compression.
- Layering by subsequent pressing has proved to be a fitting method for the **preparation of transparent ceramics with unidirectionally controlled doping content**.


## Acknowledgement

The author would like to thank for the support from the Italian Ministry of Defence under PNRM, Contract No. 8723 of 19/12/2014 (project **CeMiLAP**).


## References of interest


[1] Esposito L., Hostaša J., Piancastelli A., Toci G., Alderighi D., Vannini M., Epicier T., Malchere A., Alombert-Goget G., Boulon G. Multilayered YAG-Yb:YAG ceramics: manufacture and laser performance *J. Mater. Chem. C* **2** (2014) 10138-10148.

[2] Hostaša J., Nečina V., Uhlířová T., Biasini V. Effect of rare earth ions doping on the thermal properties of YAG transparent Ceramics. *J. Eur. Ceram. Soc.* **39** (2019) 53-58.

[3] Hostaša J., Piancastelli A., Biasini V., Pandey S. J., Martinez M., Baudelet M., Gaume R. Advances in the monitoring of the $SiO_2$ evaporation loss in transparent YAG ceramics by LIBS. *Ceram. Int.* **45** (2019) 12274-12278.

[4] Hostaša J., Piancastelli A., Toci G., Vannini M., Biasini V. Transparent layered YAG ceramics with structured Yb doping produced via tape casting. *Opt. Mater.* **65** (2017) 21-27.